World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Development of a low-cost home automation device using TSOP1738 infrared sensor and Arduino microcontroller

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World Journal of Advanced Research and Reviews, 2024, 23(03), 3120–3126

Publication history: Received on 18 August 2024; revised on 26 September 2024; accepted on 29 September 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.23.3.3025

Abstract

This paper presents the development of a remote-controlled power switching device utilizing an Arduino Nano, TSOP1738 infrared receiver, and a four-channel relay module. It manages two mains sockets, an AC bulb, and a DC bulb, with the DC circuit supported by a Li-ion battery pack that acts as a backup. The device is encased in a unit with an external power input, controlled via a standard IR remote. The Arduino Nano decodes the IR signals received from the TSOP1738, enabling user interaction. A single button can toggle all outputs, while separate buttons control each output independently. The integrated LCD provides real-time status updates of the outputs (ON/OFF). The Arduino processes the IR signals, correlates them with predefined codes, and sends control signals to the relay module to switch the connected loads. Functionality tests demonstrated consistent voltage switching, stable 5V LCD supply, and a quick 1-second response time, meeting performance expectations. The relay output showed 219V, confirming correct load handling. The 60W bulb's current was slightly above expected, but no overheating occurred, with the relay at a safe 25.3°C. The results illustrate the device's effectiveness, offering a robust method for controlling electrical devices remotely. This design presents an efficient and user-friendly solution for managing AC and DC devices, showcasing the practicality of IR technology in modern home automation.

Keywords: Arduino nano; Home Automation; Infrared Sensors; Remote Control; TSOP1738 Sensor

1. Introduction

Home automation systems are advanced technologies designed to monitor and control various household appliances and utilities, enhancing user comfort, convenience, and security [1]. The ability to remotely control appliances significantly improves the ease of managing home environments, particularly for individuals with physical limitations or busy lifestyles [2]. Traditionally, home appliances have relied on manual switching, which can be cumbersome for many users. Early remote controls were wired, which limited mobility and posed tripping hazards, but the introduction of wireless technology transformed the functionality of remote controls, allowing for greater freedom and convenience [3,4]. Modern remote controls use digital signals to manage various functions across different devices, marking a significant evolution in technology with the integration of Infrared (IR), radio frequency, Bluetooth, and motion sensors [5]. Home automation leverages multiple communication technologies, including GSM and IR sensors, to provide users with enhanced control over their appliances. For instance, GSM-based systems allow users to send SMS commands for device operation, capitalizing on the growing number of GSM subscribers worldwide. Infrared sensors detect and process IR signals, enabling efficient operation of connected devices, while advancements in remote control technology allow for seamless integration with various devices through mobile applications and voice activation [6]. In advanced home automation setups, the Arduino microcontroller plays a crucial role in interpreting signals from IR receivers like the TSOP1738. The Arduino processes these signals and executes predefined operations, offering a practical solution

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for managing electrical devices effectively [7]. This innovative use of technology demonstrates the ongoing advancements in home automation, catering to modern consumer needs and preferences.

Research in automatic switching systems reflects technological advancements in control mechanisms since the industrial revolution, illustrating the evolution from ultrasonic systems to contemporary IR control technologies [8, 9]. Modern systems utilize IR to transmit digital pulse codes for various functionalities, including power management and volume adjustments. Significant advancements have also led to the incorporation of Bluetooth, motion sensors, and voice control capabilities, enhancing user convenience. Sudhakar et al. [10] designed an automatic street lighting control system that reduced energy consumption by automating operations based on environmental light intensity [11]. The effectiveness of infrared technology in consumer electronics has been widely studied, particularly in remote controls that operate wirelessly within a limited range. The operational efficacy of these systems relies heavily on the phototransistor's optical properties in the receiver, which dictate the range and angle of operation. The electromagnetic spectrum of IR light, which spans from 0.7 to 300 micrometers, finds applications in various fields, including military surveillance, civilian remote temperature sensing, and even astronomy [12]. As wireless technologies continue to evolve, the demand for more sophisticated remote control systems grows. These devices not only simplify the management of electrical equipment but also contribute to the seamless integration of automation in daily life, reflecting ongoing innovation in automatic switching technologies. The progression towards user-friendly systems enhances the accessibility and efficiency of managing household appliances.

2. Material and methods

2.1. Design Consideration

The development of remote-controlled switching devices has garnered significant interest due to their potential for enhancing convenience and energy efficiency in household and industrial applications [13]. Various studies have explored the integration of different components, such as infrared sensors, timers, and power supply units, to create efficient and cost-effective solutions for remote control systems.

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2.1.1. Infrared Sensor-Based Switching Systems Implementation

In this project, the TSOP1738 infrared sensor was selected for its proven reliability in detecting infrared signals at a frequency of 38KHz, which corresponds to standard consumer remote controls [14]. The sensor was integrated into the circuit to receive infrared signals from a remote controller. When the remote transmitted a signal, the TSOP1738 detected it and processed it, triggering the switching mechanism. The sensor's compatibility with widely-used remote frequencies made it the ideal choice for our remote-controlled switching system.

2.1.2. Timer Circuits in Remote Control Systems Implementation

The Arduino microcontroller was utilized to decode the infrared signals received by the TSOP1738 sensor, replacing the conventional use of the NE555 timer in monostable mode [15,16,17]. The decision to use Arduino was based on its flexibility and programmability, which allowed for more complex signal processing [18]. The system was programmed to interpret the decoded IR signals and activate the appropriate switching mechanism for connected devices. In contrast to the NE555 timer, which is limited to generating single pulses, the Arduino was configured to handle a variety of commands, enhancing the versatility and responsiveness of the remote-controlled system. This shift not only simplified the circuit design but also made the system more adaptable for different applications. A schematic diagram of the design and connections is shown in figure 1.

2.2. Instrumentation and Construction

The following components are used in the design and construction of the InfraRed (IR) remote-controlled power switching device:

- The Arduino Nano serves as the brain of the device, processing the inputs from the TSOP1738 IR sensor and sending control signals to the relay module based on the decoded infrared (IR) signals from the remote controller. It manages the overall switching logic and updates the LCD display to show the status of each channel. The Arduino Nano is connected to the TSOP1738 infrared (IR) sensor via one of its digital input pins, such as pin D11, allowing it to receive incoming IR signals from the remote controller. Additionally, the Arduino is linked to the relay module through four digital output pins, for instance, D2, D3, D4, and D5, which enables it to control each of the four relays individually. For displaying the status of the system, the Arduino is interfaced with a 16x2 LCD screen using I2C communication, where A4 serves as the SDA line and A5 as the SCL line (Figure 2[a]). The entire setup is powered through the Arduino's onboard power supply, with 5V and GND pins providing the necessary power to the connected components.

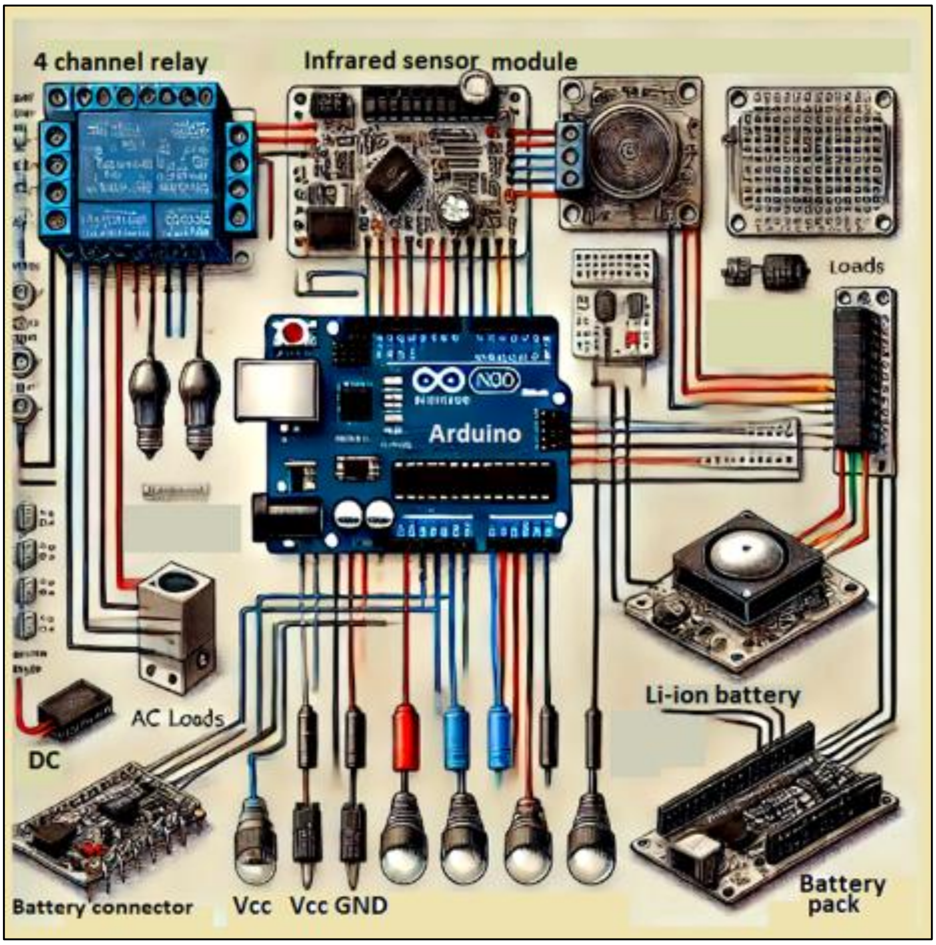
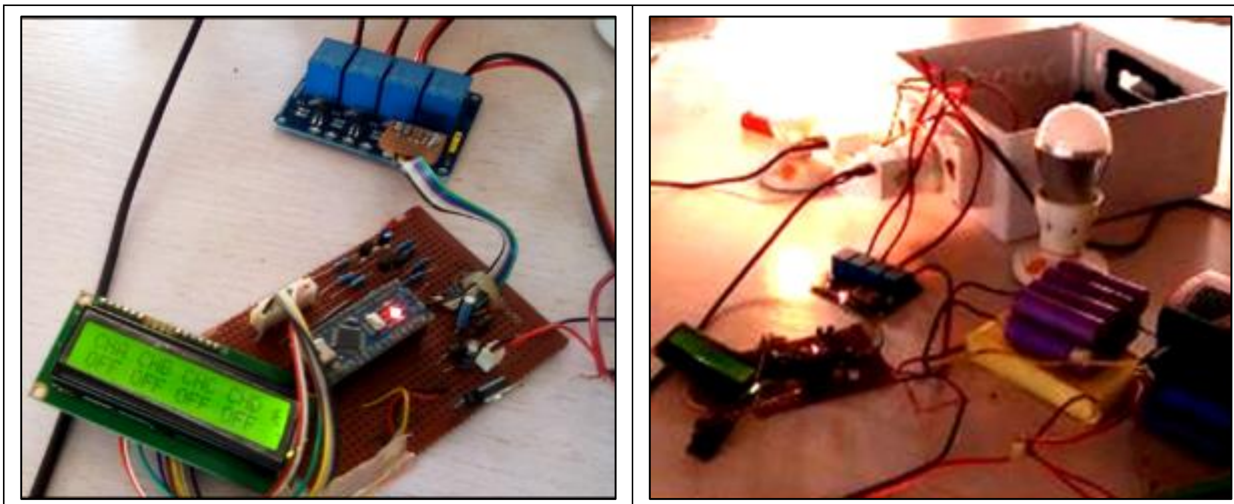


Figure 1 Schematic diagram of circuit design used for the construction

- TSOP1738 IR Receiver Sensor receives and decodes the infrared signals sent from the remote controller. It outputs a digital signal to the Arduino based on the received IR signal. The Arduino uses this data to determine which button was pressed on the remote. The TSOP1738 IR Receiver Sensor is an essential component in infrared communication systems. To set it up, the VCC pin is connected to the 5V output from the Arduino Nano, providing the necessary power for the sensor to function. The GND pin is linked to the ground of the Arduino, ensuring a complete electrical circuit. Finally, the OUT pin is connected to a digital input pin on the Arduino Nano, such as D11. This connection allows the sensor to transmit the decoded infrared signals to the Arduino for further processing, enabling seamless communication between devices.
- Remote Controller: The remote controller sends IR signals to the TSOP1738 sensor. Each button on the remote corresponds to a specific IR signal that the TSOP1738 decodes and passes to the Arduino. The Arduino recognizes the specific codes and performs the appropriate switching operations.
- The 4-Channel Relay Module (Figure 2) plays a crucial role in controlling various electrical loads, including two AC sockets, one AC bulb, and one DC bulb. When the Arduino sends a HIGH signal to a relay's control pin, it energizes the relay, causing its internal switch to change state and turn the connected load ON or OFF. To connect the relay module, the VCC pin is linked to the 5V output from the Arduino Nano, providing the necessary power to operate the module. The GND pin is connected to the ground of the Arduino, completing the electrical circuit. The IN1 to IN4 pins are then connected to the digital output pins of the Arduino (for example, D2, D3,

D4, and D5). These pins send control signals that activate or deactivate the corresponding relays. The relays feature three terminals: COM (Common), NO (Normally Open), and NC (Normally Closed), which are connected to their respective electrical loads. This setup allows for efficient switching of the loads based on the signals received from the Arduino.



(a) (b)

Figure 2 [a] Arduino connection with screen display and relay module [b] Testing the device before assembling

- AC Sockets (Two Mains-Powered Sockets: These two AC sockets allow external electrical devices to be powered or controlled by the system. They are connected to the relay outputs and are controlled by the Arduino based on the signals received from the remote controller. Each socket is wired through one relay. When the corresponding relay is activated, power is supplied to the socket, turning the connected device ON or OFF.
- Load – (a) AC Bulb: This is one of the outputs controlled by the Arduino through the relay. The AC bulb is powered directly from the mains and its power state (ON/OFF) is controlled by the relay. The AC bulb is connected to one relay. When the relay is switched ON by the Arduino, the bulb receives power and lights up, and when the relay is switched OFF, the bulb is turned off.(b) The DC Bulb is powered by a Li-ion battery pack, which also serves as a backup power supply for the entire system. The Arduino controls this bulb's ON/OFF state through one of the relays. The DC bulb is connected to the relay module. The relay is connected to the Li-ion battery pack, and when the relay is activated, the DC bulb is powered. The Li-ion battery is also connected to power other parts of the circuit, providing backup power in case of a mains power failure.
- Li-ion Battery Pack serves as the power source for the DC bulb and as a backup power source for the entire system, ensuring it continues to function in case of mains power loss. The battery pack is wired to the relay controlling the DC bulb. It may also be connected to the Arduino Nano's Vin pin to provide power to the system in case the mains power fails.
- 16x2 LCD (I2C): The LCD screen provides visual feedback to the user, displaying the current status (ON/OFF) of each of the four channels. This ensures the user is aware of the system's state at any time. The LCD is connected to the Arduino Nano via I2C communication, using the A4 (SDA) and A5 (SCL) pins. It is powered through the 5V and GND pins from the Arduino.
- Power Supply (for Mains Devices): Provides power for the AC sockets and the AC bulb. This is essential for powering the devices connected to the relays. The power supply is connected through the relays to the AC sockets and the AC bulb, allowing these devices to be powered ON or OFF based on relay control.

Wires were used to connect all components electrically. The wires connect the Arduino to the IR sensor, relays, LCD, and power supply. The printed circuit board (PCB) provides a platform for mounting and connecting the components in an organized and stable manner. Casing is done using plastic cuboid 6"x6"x2" which protects the device and components while giving it a neat appearance. It contains all the electronics, including the bulbs, sockets, and Li-ion battery.

3. Testing and Results

In this system, the user begins by pressing a button on the remote controller (Figure 3[b]). The TSOP1738 IR receiver decodes the infrared signal and relays it to the Arduino Nano. Once the Arduino receives the signal, it processes the information to determine which button was pressed, subsequently activating or deactivating the appropriate relay or relays. As the relays toggle, they control the connected electrical loads, such as sockets and bulbs, turning them ON or OFF as commanded. To ensure the user is kept informed, the status of each channel is continuously updated and displayed on a 16x2 LCD, allowing for real-time monitoring of the system's operations. This configuration results in a versatile power control system, perfect for home automation or any application that requires remote switching of both AC and DC loads. The results of the tests conducted demonstrate the effectiveness and reliability of the system. Table 1.0 shows the response of the device when loaded and switched by the remote controller.

Table 1 The response values and observation during testing of the device

Test Type	Parameter	Measurement Method	Expected Voltage Response (V)	Actual Voltage Response (V)	Observations
Load Testing	Voltage at relay output	Measured with a multimeter when bulb is ON and OFF	220V (for ON), 0V (for OFF)	ON – 219V OFF – 0V	Relays handle the load correctly
	Current through the bulb	Ammeter in series with the bulb	~0.27A (for 60W bulb at 220V)	0.29A at 219V	No tendency for overheating or malfunction detected.
	Relay temperature	Infrared thermometer	< 70°C	25.3°C	Normalrelay performance during testing.
Functionality Testing	Voltage across each channel (CHA, CHB, CHC, CHD)	Measure voltage at relay output for each channel	220V (for ON), 0V (for OFF)	220V (for ON), 0V (for OFF)	Switching for each channel properly functioning.
	Voltage on LCD display	Measure voltage supply to LCD	5V	5V	Good functionality of user interface
	Response time	Measure time taken to switch ON/OFF	< 2 seconds	1second	Timely response to remote signals achieved.

During load testing, the voltage at the relay output measured 219V when the bulb was ON, confirming that the relays handle the load correctly, with an expected voltage response of 220V. The current through the 60W bulb was measured at 0.29A, slightly higher than the expected 0.27A, but no overheating or malfunction was detected, with the relay temperature remaining at a normal 25.3°C. Functionality testing showed that each channel (CHA, CHB, CHC, CHD) maintained a consistent voltage of 220V when activated and 0V when deactivated, indicating proper switching functionality. The voltage supply to the LCD was stable at 5V, ensuring good user interface functionality. Additionally, the response time for switching ON/OFF was recorded at just 1 second, achieving the desired threshold of under 2 seconds for timely responses to remote signals. Overall, these results affirm that the system operates efficiently and effectively, fulfilling its intended purpose in home automation applications.

(a) (b)

Figure 3 (a) Coupling of the constructed device and (b) the rear view of the already cased device -

4. Conclusion

This project successfully developed a cost-effective and efficient home automation device utilizing the TSOP1738 infrared sensor and Arduino Nano microcontroller. The system's ability to remotely control both AC and DC loads, coupled with real-time feedback via an LCD display, highlights its practicality for everyday home automation needs. The integration of infrared technology and programmable logic through Arduino proved effective in ensuring seamless operation, with timely response rates and consistent voltage regulation across all connected devices. The project demonstrates the potential of low-cost automation systems to enhance user convenience and energy efficiency in household applications. The findings show that the system is not only reliable but also versatile, providing a robust solution for managing electrical loads remotely. Future research could explore further enhancements, such as integrating wireless communication protocols like Wi-Fi or Bluetooth, to extend the system's capabilities and applications beyond basic remote control.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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